

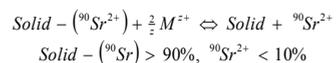
Microbially Facilitated Calcite Precipitation for Remediation of Strontium-90 (EMSP Project 87016)

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Immobilization Strategy

In Situ Stabilization of ⁹⁰Sr by Co-Precipitation in Calcite

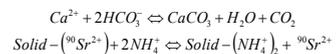
Cation exchange of ⁹⁰Sr (and other metals) sorbed to aquifer rock serves as a continuing source of groundwater contamination



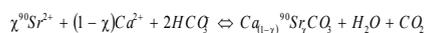
Microbially catalyzed hydrolysis of urea will produce bicarbonate ions, ammonium ions, and raise pH:



Bicarbonate ions promote precipitation of calcite. Ammonium ions promote exchange of sorbed ⁹⁰Sr:

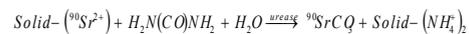


⁹⁰Sr co-precipitates into calcite and is removed from groundwater:



Continued precipitation of "clean" calcite removes ⁹⁰Sr from contact with groundwater.

Net in situ Stabilization Reaction for ⁹⁰Sr



In environments already supersaturated with respect to calcite (e.g., much of arid western U. S.), any new calcite precipitated will remain stable even after return to pre-manipulation conditions.

The half-life of ⁹⁰Sr is 29 yrs; after 300 yrs >99.9% of radioactivity is gone.

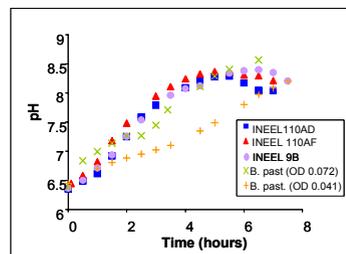
Acknowledgments

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Research Progression

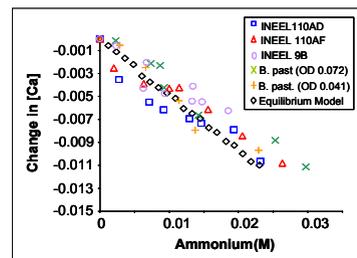
Proof of Principle

Model Ureolytic and Snake River Plain Aquifer Bacteria

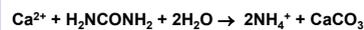


pH evolution during calcite precipitation experiments.

Ammonium Generation and Calcite Precipitation

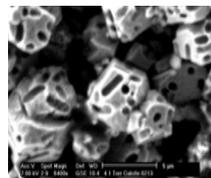


Net reaction:

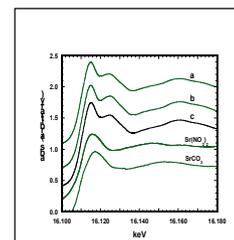


Development of Characterization Tools

Characterization of Calcite and Strontium-Containing Calcite

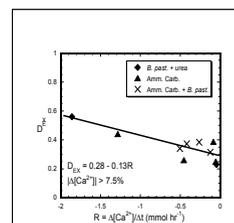


Scanning electron micrograph of biologically generated calcite.



Sr K-edge XANES: shows Sr as solid solution, not sorbed.

- XRD shows only calcite.
- Sr incorporation higher in ureolytically generated calcite compared to calcite generated abiotically by ammonium carbonate addition.

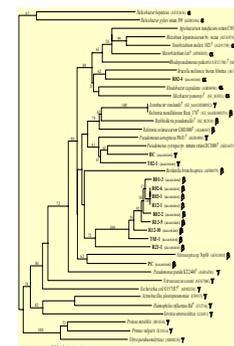
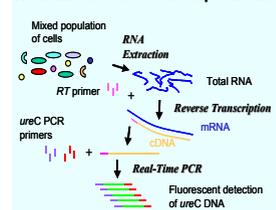


D_{EX} for Sr in calcite is function of precipitation rate.

Molecular Indicators of Microbial Ureolytic Capabilities

- PCR primers for the ureC gene have been developed, based on ureolytic groundwater isolates and known organisms.
- qPCR technique developed; RT-PCR under development.

Real-time Reverse Transcription PCR

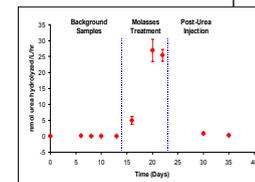
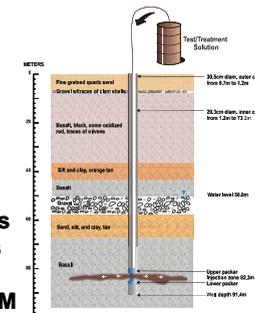


Phylogenetic analyses show some general congruency between 16S rDNA and ureC trees, but not enough to identify species by ureC.

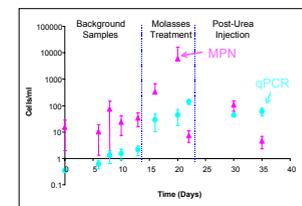
Initial Field Studies

One well test in Snake River Plain Aquifer, ID

- Packers isolated 2m zone of consolidated basalt.
- Three dilute molasses (0.00075%) injections over 2 weeks, then one injection of 50 mM urea.



Estimated in situ ureolysis rates, measured with ¹⁴C urea.



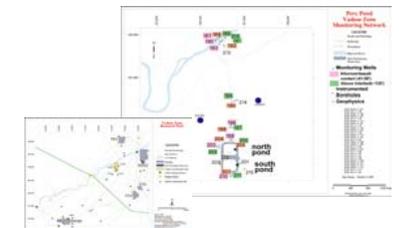
Ureolytic cells, by MPN and qPCR.

Planned Field Studies

Static Multi-level sampler experiments

- In same well as previous field test, but instead of injection, nutrients will diffuse out into aquifer.
- Continuous logging of pH, conductivity, Eh.
- Recovery of solids (biomass, calcite) on Bio-Sep beads and basalt.

INEEL Vadose Zone Research Park (VZRP)



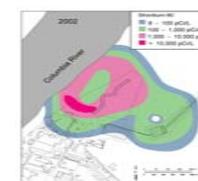
- Two ponds that receive process water from INTEC facility; instrumented for studies of vadose zone flow and transport.
- Currently being used for another EMSP project (Roback et al.) aimed at developing conceptual models for contaminant migration through thick, layered and fractured vadose materials. Also envisioned as a component of a potential future FRC that would support research of vadose zone contaminant migration.

At instrumented boreholes, data are collected automatically and transmitted to INEEL computer network over radio link.

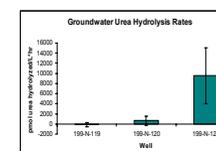


- VZRP is an uncontaminated analog site for INEEL INTEC perched water ⁹⁰Sr contamination (320,000 pCi/L).
- Push-pull type tests planned in shallow (~40') wells.

Hanford 100-N Area



⁹⁰Sr is contaminant of concern in groundwater; plume discharging into Columbia River.



Ureolysis rates and ureolytic cell numbers for Hanford groundwater samples show significant ureolytic activity; 10 to 1000 X more than SRPA. Sediments also showed activity (data not shown).